UBD/MPD FLOW MODELLING

What is Underbalanced Drilling?

The International Association of Drilling Contractors defines Underbalanced Drilling (UBD) as, “a drilling activity employing appropriate equipment and controls where the pressure exerted in the wellbore is intentionally less than the fluid pressure in any part of the exposed formation.” To achieve an underbalanced condition, a gas-liquid mixture is often used in place of conventional drilling mud. The result is that multiphase flow can be present in every aspect of a UBD operation. This presented new challenges for drilling engineers who had historically dealt strictly with conventional drilling mud (i.e. an effectively incompressible, single-phase fluid) for which the hydraulics focused on mud weight and the corresponding hydrostatic head. In UBD they were dealing with complex behaviour associated with mixtures of gases and liquids (both drilling fluids and produced fluids).

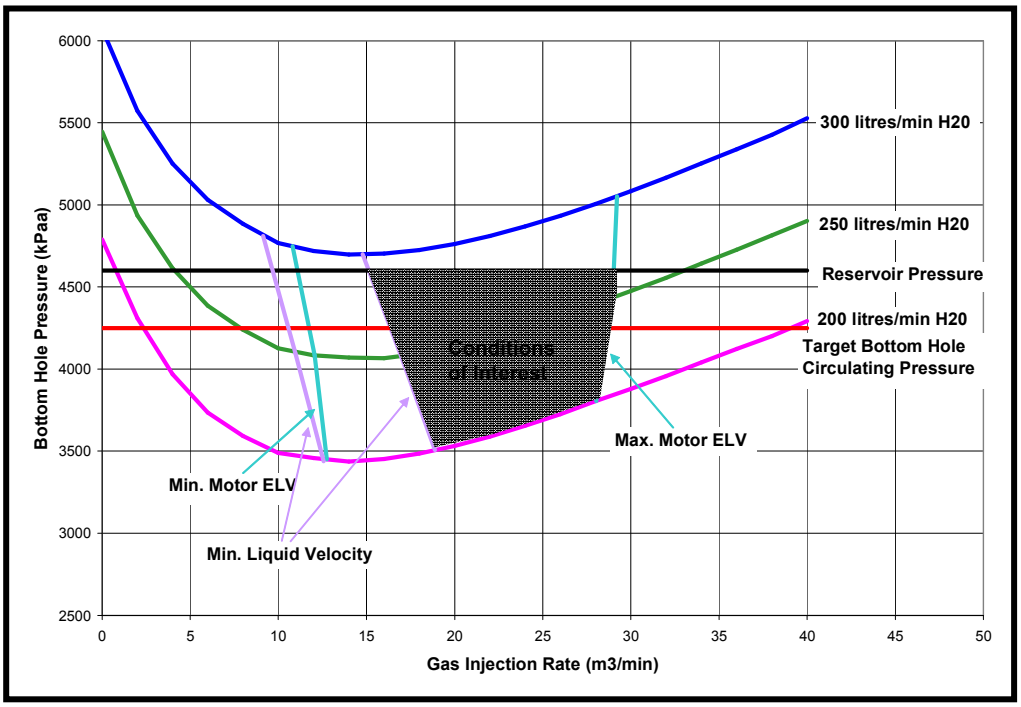
The early 1990s saw a dramatic growth in UBD as it became popular for drilling horizontal wells. Maintaining an underbalanced state allows reservoir fluids to enter the wellbore while drilling operations proceed, thus preventing flow of drilling fluids (and associated solids) into the formation, thereby minimizing or even eliminating formation damage. This is of particular importance in the drilling of horizontal wells as the formation is exposed to the drilling fluids for an extended period of time. Although the initial goal of such UBD operations was to reduce formation damage, it was soon realized that UBD techniques could also lead to improved recovery, reduced requirement for stimulation, and early production. As a result of this focus on maximizing hydrocarbon recovery, the application of UBD expanded into a variety of new areas and the new technologies required to support this growth were developed.

How did WELLFLO become the industry standard in UBD flow modelling?

With the growth in the application of UBD came the recognition that in order to apply these new drilling methods safely and effectively, detailed engineering was required. One aspect of this detailed engineering involves the use of multiphase flow modelling software to analyze the behaviour of the gas-liquid mixtures commonly used as drilling fluids for UBD. In the early 1990s, Neotec was approached by several engineers working in UBD. They were aware of our reputation for modelling the production of gas-liquid mixtures and hoped that we would be able to adapt that expertise to a new application. Since that time, Neotec has been continuously involved in providing drilling engineers with an effective tool for modelling the drilling of wells in an underbalanced state. In 1995, Butler and Gregory published one of the earliest papers on the subject. As a result of this ongoing effort, Neotec’s steady-state thermo-hydraulic model, **WELLFLO**, has become the industry standard in UBD flow modelling.

An obvious example of the cooperative development work between Neotec and the drilling community is the UBD operating envelope shown below. When initially created by innovative UBD engineers working with **WELLFLO**, an operating envelope for underbalanced drilling took these experts more than a week to create – running individual cases and manually manipulating the results in spreadsheets. Once Neotec

was aware of the need for these plots and had seen the value associated with them, the ability to create them was added as a special feature in **WELLFLO**. As a result, UBD operating envelopes can now be created in a fraction of the time that was originally required.



The development of such tools has progressed to the point that Mykytiw *et. al.* have stated that, "UBD operations are synonymous with multiphase flow modelling." These same authors go on to say that "Multiphase flow simulation is an integral element in the preliminary engineering, circulating system design, well controllability analysis and equipment selection process for any underbalanced drilling operation." Their paper offers a very practical insight into the range of applications that are addressed with flow modelling during the creation of an underbalanced drilling program.

The significance of Neotec's contribution to the literature on the subject of multiphase flow modelling for UBD was acknowledged with the inclusion of a paper by Smith, Gregory, and Brand (*Application of Multiphase Flow Methods to Underbalanced Drilling Pilot Test Data*) in SPE's *Underbalanced Operations Reprint No. 54,* a collection of papers that "focuses on the best practices across the spectrum of the technology." This paper reports agreement between the measured and predicted pressure losses with an error of less than 6.5% when using Neotec's recommended procedures for drilling applications. This average accuracy was achieved for the 51 sets of measured data that were collected during field tests conducted by Mobil Oil Indonesia.

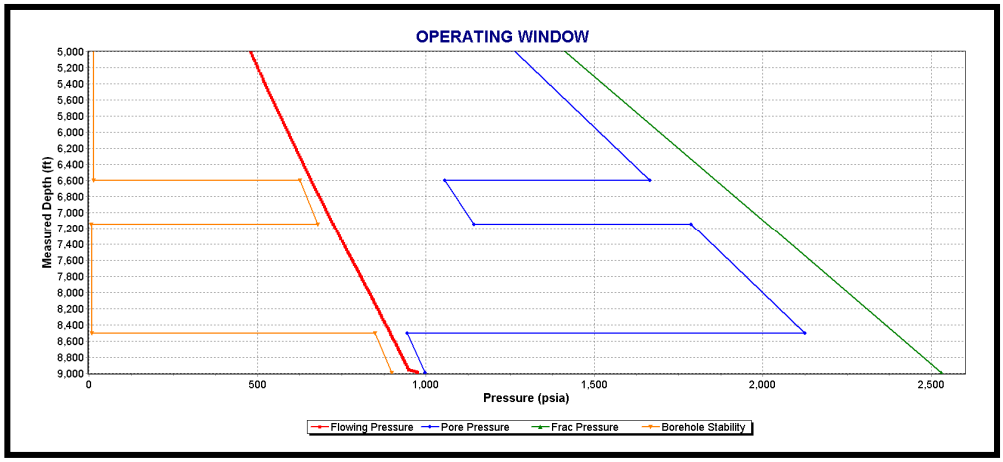
What is Managed Pressure Drilling?

The recognition of the benefit of UBD in terms of reduced formation damage, particularly in horizontal wells led to a boom in the application of UBD. The successes in the development and application of underbalanced drilling technology led to the application of these technologies in areas where mitigation of formation damage was not the primary focus and where operation in underbalanced conditions was not necessarily required. The growing application of UBD technologies in operations that would not be, by definition, underbalanced (i.e. near- and overbalanced) has ultimately led to the adoption of the new term, Managed Pressure Drilling (MPD).

The IADC defines MPD as “an adaptive drilling process used to precisely control the annular pressure profile throughout the wellbore. The objectives are to ascertain the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly.”

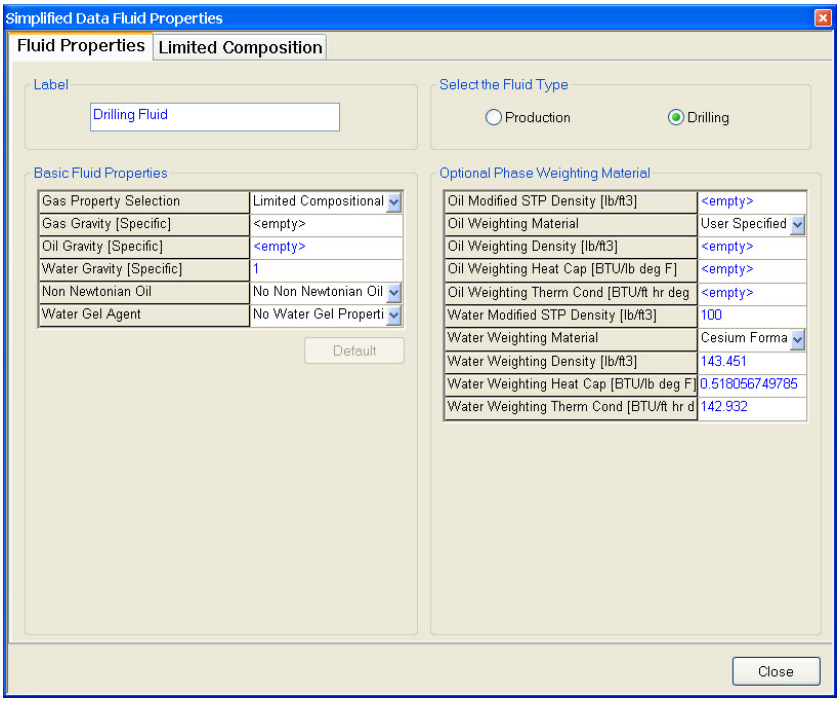
The benefits of UBD have often been generally defined in terms of three key points: maximizing hydrocarbon recovery, elimination of drilling problems, and early development of reservoir data. UBD and MPD are often distinguished in terms of these benefits. UBD is reservoir-focused; driven by the prevention of formation damage and the acquisition of reservoir data. The maintenance of an underbalanced state is by definition a requirement of UBD. MPD is drilling-focused; targeting the elimination of problems such as lost circulation and differential sticking. Thus, MPD does not require the maintenance of an underbalanced pressure; instead it focuses on controlling the annular pressure profile.

IADC appended several interesting technical notes to the definition of MPD referenced above. One of these states that “MPD may include control of back pressure, fluid density, fluid rheology, annular fluid level, circulating friction, and hole geometry, or combinations thereof.” This note highlights the fact that flow modelling, such a key element in the planning and implementation of UBD projects, is also a necessary element of these same processes for MPD projects. Neotec continues to add both features and technologies to **WELLFLO** that improve and expand its effectiveness for use on both UBD and MPD projects. The MPD Operating Window (shown below) and advanced features for handling the conventional drilling mud often used in MPD were added to **WELLFLO** 7.3.



Neotec's efforts in the area of flow modelling for UBD and MPD have not been without challenges. Certainly the greatest of these challenges has been learning to understand the language that is used by drilling engineers (for example, equivalent circulating density in place of flowing bottomhole pressure) and the ways in which they apply the flow modelling results.

Neotec President Steve Smith often recalls an incident from the early days of Neotec's involvement in UBD. "I was in a client's office and was asked if it was possible to plot bottomhole pressure vs. wellhead pressure using **WELLFLO**. Without the first clue as to why anyone would want to do this, I confirmed that it was possible and showed the user how to do so. It was only later that I came to understand the importance of such a plot in recognizing the well control characteristics associated with a drilling operation."



Neotec has been very fortunate that, for more than 15 years, we have been involved with many of the pioneering individuals and companies involved in the evolution of UBD and MPD technology. It has been our pleasure to deal with companies involved in all aspects of the drilling process including operators (including Shell, BP, ConocoPhillips, Total, and Saudi Aramco), engineering firms (including Blade, Flow Drilling Engineering, and Leading Edge Advantage), and service companies (including Weatherford, Halliburton, and Schlumberger). The list of individuals that we have had the pleasure of dealing with is far too lengthy to include here, but we must acknowledge a few individuals. Special thanks are due to Bob Teichrob and Stu Butler who first introduced us to UBD while they were working with Husky in Western Canada. Additional thanks go out to Pat Brand and Phil Frink who used **WELLFLO** on the Arun project undertaken by Mobil Oil and as a result, introduced us to the international drilling community.